Charge-air cooler for motor vehicles

The invention relates to a heat exchanger for motor vehicles, in particular a charge-air cooler, in particular for utility vehicles, according to the precharacterizing clause of patent claim 1.

Heat exchangers, such as, for example, charge-air coolers for motor vehicles nowadays, often have a soldered heat exchanger unit which is constructed from flat tubes, corrugated fins and tube bottoms which receive the tube ends. Header boxes, for example what are referred to as air boxes, are placed onto the tube bottoms and are connected tightly thereto. The header boxes - even in the case of utility vehicles - are frequently produced from plastic and are connected to the tube bottoms mechanically, for example by means of a flared joint with a rubber seal. The header boxes are sometimes also designed as cast aluminum boxes which are welded to the tube bottoms which are likewise produced from an aluminum material. Charge-air coolers with plastic air boxes have been disclosed, for example, by DE-A 199 53 785 and DE-A 199 53 787 of the applicant. At relatively high temperatures, for example above 220° Celsius of the charge air, as can be expected in the case of future developments, plastic air boxes no longer withstand the pressure and temperature stresses - in this case, air boxes made from a metallic material, for example cast aluminum, are used. These cast air boxes are produced in a permanent mold casting process which provides diverse creative possibilities but is very complicated and cost-intensive.

It is an object of the present invention to improve a heat exchanger of the type mentioned at the beginning to the effect that the header boxes withstand

relatively high temperatures and pressures without the production costs substantially rising.

This object is achieved by the features of patent claim 1. According to the invention, it is provided that at least part of at least one header box is produced from a semifinished product by means of internal high-pressure forming (IHF). The use of a metallic semifinished product enables the stresses occurring due to temperature and pressure to be controlled. In addition, the costly permanent mold casting process is avoided and, instead, a cost-effective semifinished product is used which is deformed by the cost-effective IHF process.

The internal high-pressure forming, which is referred to as the IHF process, is known per se, for example from DE-A 102 04 107 for a metallic housing of an exhaust gas heat exchanger, into which an expansion bead is molded by means of IHF. In the IHF process, also called hydroforming, closed housing parts are "inflated" by means of a liquid pressure medium (water). The parts to be deformed are placed into molds of corresponding contour and are then acted upon from the inside by means of a pressurized liquid in such a manner that the material of the housing is placed against the contour of the die.

According to an advantageous refinement of the invention, only the cover is deformed from a semifinished product in the IHF process and is welded to a conventional tube bottom. This measure already brings a reduction in the production costs, in particular if, advantageously, a rolled aluminum sheet is used as the semifinished product for the cover.

In a further advantageous refinement of the invention, both the cover and the tube bottom can be produced from

a semifinished product by the IHF process. The integration of the tube bottom brings a further reduction in cost, since bottom and cover are produced from the same semifinished product, advantageously an extruded aluminum tube. The shaping of the entire header box composed of bottom and cover may take place by means of the IHF process with which a multiplicity of possibilities with regard to the shaping are produced.

According to a further advantageous refinement of the invention, the entire header box, comprising bottom, cover and connecting pipe, is produced as a single piece from a semifinished product by means of the IHF process. This advantageously takes place using an extruded semifinished aluminum tube which is first of all prebent in order to form a connecting pipe for the header box, so that the connecting pipe obtains its direction in relation to the rest of the air box. After that, a longitudinal bead is placed into the for example round semifinished product by pressing from the outside, i.e. over part of the length of the header box, thus resulting in a header box cross section which tapers from the connecting pipe toward the opposite end side. This shaping assists the flow of a medium in the header box. In addition, this flattening of the header box affords the advantage of improved installation conditions in a motor vehicle. The final shape is produced by IHF by the semifinished product material being pressed from the inside against the contour of the die by the high pressure. The advantages of this header box produced according to the invention are high temperature and internal pressure strength owing to the semifinished product material used and the closed cross section, and also low production costs on account of the cost-effective IHF process.

The connecting pipe is advantageously designed as an end-side extension of the header box. In a variant,

instead of the end-side connecting pipe or in addition to the end-side connecting pipe, a connecting pipe is arranged laterally on the header boxy, in particular is welded or soldered to the header box.

According to an advantageous refinement of the invention, the end surface which lies opposite the connecting pipe is closed by a cover which can be soldered into place. A tight and pressure-resistant connection and a closure of the header box are therefore achieved.

According to a further advantageous refinement, the connecting pipe is designed as an extension of the header box and/or covers an end surface of the header box by the connecting pipe.

According to a further advantageous refinement of the invention, the openings, which are referred to as rims, in the bottom of the header box are produced by punching, to be precise in particular by punching counter to hydraulic internal high pressure, as is known from DE-A 195 32 860 of the applicant. This process affords the advantage of "technology pure" manufacturing, since a hydraulic internal high pressure is built up both for the shaping of the header box and for the production of the rims, with the same devices being useable. This reduces the manufacturing costs and, furthermore, has the advantage, under some circumstances, of forming without cutting.

According to an advantageous variant, the openings are optionally prepunched in the bottom and are produced by drawing through, with the drawing through particularly preferably taking place counter to a hydraulic internal high pressure. This also reduces the manufacturing costs and, furthermore, has under some circumstances the advantage of forming without cutting.

The header box is preferably designed with a wall thickness which is, in particular, continuously, between 2 mm and 5 mm, particularly preferably between 3 mm and 4 mm. In particular the stability of the heat exchanger to pressure is increased by this means without the manufacturing outlay rising unacceptably.

According to advantageous embodiments, the bottom has a curvature and/or the header box has a stepless and/or kink-free cross section, in particular continuously. By this means, under some circumstances, the header box is less deformed in the event of pressurization and its stability to pressure is increased. In this case, a radius of the curvature of the bottom is particularly advantageously and particularly continuously between 100 mm and 400 mm, preferably between 200 mm and 300 mm. In the transition region to the cover, a radius of curvature of the bottom, here viewed in cross section, is preferably between 5 mm and 20 mm, particularly preferably between 10 mm and 15 mm. When one or more parameters within the ranges mentioned are kept to, a heat exchanger according to the invention has, under some circumstances, a particularly high stability to pressure.

An exemplary embodiment of the invention is illustrated in the drawing and is described in more detail below. In the drawing

Fig. 1 shows a charge-air cooler according to the invention,
Fig. 2 shows a corner detail of the charge-air cooler according to the invention shown in Fig. 1,
Fig. 3 shows a first cross section through an air box of the charge-air cooler according to Figs. 1 and 2, and

Fig. 4 shows a second cross section through the air box.

Fig. 1 shows a charge-air cooler 1 according to the invention with a heat exchanger unit 2 and air boxes 3, 4 arranged on both sides. The heat exchanger unit 2 is composed of flat tubes 5 and corrugated fins which are arranged between the latter and over which ambient air flows. The tubes 5 lead into the air boxes 3, 4 and are soldered thereto and to the corrugated fins 6. All of the parts, tubes 5, corrugated fins 6 and air boxes 3, 4 are composed of aluminum alloys. Each of the two air boxes 3, 4 is of single-piece design and is composed of three sections (explained with regard to the air box 4), namely a connecting pipe 7, a cylindrical part 8 (not circular-cylindrical) and a conical or flattened part 9 which has a longitudinal bead 10 running in the longitudinal direction of the air box 4. The connecting pipe 7 has a rectilinear part 7a which adjoins the rectilinear air box part 8 in alignment therewith and has an elbow 7b bent approximately through 90° to 120°. The air box 3 is designed in mirror-inverted manner with respect to the air box 4 and has a charge-air inlet connecting pipe 11. The charge air which has been compressed by a compressor (not illustrated) of a motor vehicle and has an increased temperature enters the inlet connecting pipe 11, is distributed via the air box 3, flows through the heat exchanger unit 2 and the tubes 5 thereof in one direction and passes into the opposite air box 4 from which the charge air emerges through the outlet connecting pipe 7. Since the charge-air cooler 1 in this case is of symmetrical construction, a reverse direction of flow, i.e. entry into the connecting pipe 7 and exit through the connecting pipe 11 is likewise possible. As known from the prior art cited at the beginning, the charge-air cooler 1 is arranged in the front engine compartment of

the motor vehicle, frequently as part of a cooling module.

Fig. 2 shows a corner region of the charge-air cooler 1 according to Fig. 1 with the air box 4 into which the tubes 5 lead. The heat exchanger unit 2 is closed laterally by means of a side part 12. The air box 4 has an end surface 13 which is closed by a cover 14 soldered into it. The profile of the longitudinal bead 10 can be seen clearly in the end surface 13.

Fig. 3 shows a section through the air box 4 approximately in the region of the section line III-III in Fig. 1 and in the region of a tube 5, with the tube 5 being omitted. The air box 4 has a closed, single-piece cross section 15, since it is produced from a closed tube, an extruded semifinished aluminum tube. The cross section 15 is characterized by a slightly outwardly curved bottom region 15a, two wall regions 15b, 15c running approximately perpendicularly thereto and a bead region 15d which lies opposite the bottom region 15a and is impressed by the bead 10. The wall regions 15b, 15c and the adjoining bead region 15d form the "cover" of the air box 4, and the bottom region 15a forms the "bottom". Bottom and cover are therefore integrated and together form the air box 4. An elongate opening 16 which corresponds in its cross section to the cross section of the tubes 5 or the tube ends thereof, which are soldered into these openings, is arranged within the slightly curved bottom 15a. The cross section 15 has a cross-sectional area 17.

Fig. 4 shows a further section through the air box 4 in the region of the cylindrical section 8 along the line IV-IV in Fig. 1. The air box 4 has in the region 8 a closed cross section 18 which is characterized by a slightly curved bottom 18a and a partially curved, partially rectilinearly extending cover region 18b. An

elongate opening 19 (rim) for receiving a tube (not illustrated) is arranged in the bottom 18a. The integration of cover and bottom can also be seen from this cross section 18. It is also possible to design the air box 4 over its entire length with the cross section 18, i.e. a constant cross section, if, for installation reasons, the flattened part 9 (cf. Fig. 1) may be omitted.

The production of the air box 4 and of the air box 3 takes place according to the following process: the starting material is a semifinished aluminum tube which is matched with regard to its wall thickness to the pressure and temperature loading of the charge-air cooler. The extruded semifinished tube, which has a circular cross section, is first of all cut to size (cut to length), then the connecting pipe (7, 11) is prebent, i.e. it obtains its bending radius and its direction in this process step. The tube is then placed into a device and, by means of pressure from the outside by means of a wedge-shaped die (not illustrated), obtains a preparatory shape of the final longitudinal bead 10. The tube is subsequently placed into a mold for the internal high-pressure forming and is acted upon by internal high pressure, so that the tube wall of the tube is placed against the inner contour of the mold. The final shape of the air box (4, 3) is thereby achieved. As illustrated in Fig. 1, the longitudinal bead 10 only extends over part of the length of the air box 4, but may also extend over the entire part or a smaller part of the overall length. As can also be seen from Fig. 1, the bead 10 is of conical design, i.e. it increases with regard to its depth and its width in the direction of that end of the air box 4 which faces away from the connecting pipe 7. The cross section of the longitudinal bead 10 can be seen from Fig. 3; it is characterized by a width B, a depth T and a cross-sectional area 10a (shaded gray). The cross-

sectional area 10a increases in a direction starting from the connecting pipe 7, i.e. the cross-sectional area 17 of the air box 4 becomes smaller with increasing distance from the inlet or outlet connecting pipe, by contrast the circumference of the air box 4 remains essentially constant or increases at maximum by a range of 10% to 15%. This cross-sectional reduction fits in well with the flow conditions in the air boxes, since the volumetric flow of charge air increases in the direction of the connecting pipes on account of the tube distribution. However, the beveling of the air box 4 in the region of the section 9 also takes place for installation reasons in order to obtain space in this region.

The openings 16 (cf. Fig. 3) in the bottom 15 of the air box 4 may preferably be produced by punching, with, instead of a die-plate, a hydraulic internal high pressure being built up in the interior of the cross section. This process for producing rims in tubes is disclosed by DE-A 195 32 860 of the applicant. It affords the advantage of production without cutting. In addition, the same devices as for the internal high-pressure forming of the air boxes 3, 4 can be used.